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ABSTRACT

Accepting that language diversity is functionally related to other variables characterizing human societies, much discussion stems from the advantages or disadvantageous nature of language diversity in terms of national development and national unity. To discover ways of measuring language diversity would help, in part, to solve the language diversity issue; however, the lack of consistency and agreement in the definition of the two viewpoints hampers the language planners. Bearing in mind that any language diversity measure takes into consideration all languages present and considers the numbers of users of the languages, the coupling of these two independent variables renders the elimination of all ambiguity impossible in a diversity measure. For example, a society bearing a large number of languages with widely differing numbers of users will have the same diversity measurement as one characterized by a smaller number of languages but greater evenness of user distribution. The diversity measurement must be related to both the number of languages and the degree of evenness of user distribution. Using indices and equation models of the research of language planners, this document sets out to define properties which a language diversity index should exhibit, using both sample and census data. (Author/CE)

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THE MEASUREMENT OF LANGUAGE DIVERSITY

INTRODUCTION

If is frequently asserted that language diversity is functionally related to other variables characterising human societies. (See, for instance, Greenberg 1956, Gumperz 1962, Fishman 1968a, 1968b, 1977, Pool 1969, Lieberson & Hansen 1974). A perennial bone of contention, for example, has been the advantageous or disadvantageous nature of language diversity in terms of national development and national unity (Fishman 1963, Deutsch 1966, Siméon 1972). As Pool (1969) has pointed out, however, the current ability of language planners to estimate the relevance of language diversity to development is almost nil, and one of the main reasons for this is the lack of consistency and agreement in the definition of the two concepts involved. The purpose of the present article is not to add to the development/diversity debate, but rather to suggest reasonable and internally consistent ways of measuring language diversity. It is hoped that this contribution will enable ensuing discussions of the relationship between diversity and other variables to be pursued upon the basis of less ambigous, comparable evaluations of this elusive phenomenon.

Desirable Properties of a Language Diversity Index

Although Pool (1969) emphasises the wooliness of contemporary definitions of the concept of language diversity, he continues to employ an apparently arbitrary definition in his attempt to clarify the relationship between this variable and national development. The measure used in his article was the size of the « largest native language community (% of population) »[1] and variations on this theme have frequently appeared in the literature (Banks & Textor, 1963, Fishman, 1968, Fishman, Cooper and Rosenbaum, 1977, Criper and Ladefoged, 1971). Although the most straightforward and unambiguous way of measuring language diversity is simply the number of languages[2] coexisting within a given observational unit, almost all writers have in fact sought to incorporate numbers or proportions of language users into their diversity measures. The general consensus of opinion would appear to be that the more even the distribution of users among the language categories the greater the language diversity of the unit in question. Some writers, however, characterise the units under observation as being diverse or homogeneous without regard to the numbers of different languages in use within them. Banks and Textor, (1963) for instance, define polities in which one language is natively spoken by 85% of the population and in which no significant linguistic minority is present as being less diverse than polities in which the remaining 15% of speakers may be assigned predominantly to a single lan-

[1] Pool, p. 148.

[2] Throughout this article it is assumed that a discrete classification of languages is feasible.

guage[3]. This can give rise to considerable ambiguity in that the members of the former class are actually likely to exhibit a larger number of languages and yet be classified as less diverse.

It is the opinion of the present writer that any language diversity measure must take into account first and foremost *all* the languages present but should also seek to incorporate the legitimate concern expressed by most writers for the numbers of users of these languages. Although it is not anticipated that this goal will be disputed, it should be borne in mind that the coupling of two independent variables, namely number of languages and the distribution of speakers among them, renders the elimination of *all* ambiguity impossible in a diversity measure. It is quite possible, for instance, that a society featuring a large number of languages, with widely differing numbers of users will have the same diversity measurement as a society characterised by a smaller number of languages but greater evenness of user distribution. Any diversity measurement should therefore be evaluated in the light of both the number of languages and the degree of evenness of user distribution (see p. 6).

The desire to incorporate numbers and distributions of speakers in a diversity index calls for another caveat at this point. As Fishman (1968b) has pointed out, the demographic status of a language does not necessarily coincide with its use and functions within a given society. A fundamental aspect of any demographically based measure of diversity is, therefore, that it constitutes a surrogate measure of the diversity of a limited subset of the total set of linguistic *activities*. The type of linguistic activity whose diversity it is required to measure should be clearly specified at the outset. It is for this reason that the more general locution 'language users' is prefered to that of 'language speakers' throughout this theoretical paper. A language may be widely read and therefore used in the context of work, for instance, without being spoken. Indices based on numbers or proportions of native speakers, on the other hand, tell us something about the diversity of languages spoken in the homes of a given census or survey unit at sometime in the past, (providing migration is allowed for). They cannot be taken to describe diversity of actual linguistic *activity* outside the home at a later point in time, as Lieberson (1968), for example, seems to assume in his development of Greenberg's diversity index. As mother tongue data are by far the most commonly used for diversity measurement purposes, it must be further emphasised that, since home languages (and therefore mother tongues) vary over time, evaluations of diversity rooted in demographic data should not be based on widely differing age groups unless one is simply interested in measuring the mother tongue diversity of a set of human beings *per se*. An example may help to make this clear. A mother tongue based measure of the diversity of the population in the North West Highlands of Scotland, which did not control for age, would produce a reasonably high diversity value. It would be erroneous, however, to conclude that this represents the diversity of linguistic *activity* in the region's homes at any one point in time. For the older members of the population (≥60) the home language was almost exclusively Gaelic whereas for the younger generation (≤20), English has been more or less unchallenged as the language of the home. The degree of mother tongue diversity among the population as a whole at the present time is undoubtedly higher than that of linguistic *activity* among the region's homes at present or indeed at most periods in the past. Mother tongue diversity then can only be used as a surrogate

[3] Lieberson (1975) has shown that the size of the largest mother tongue group is in fact an excellent nonlinear predictor of one of the more satisfactory measures of diversity, Greenberg's A-index, defined below.

measure for *home* linguistic activity within a societal unit, and should ideally be calculated using data in which age has been controlled for (age cohorts).

As stated on page (2) the inclusion of both numbers of languages and the distribution of users of these languages in a diversity measure will inevitably entail a certain degree of subjectivity, as the calculated values will depend upon the definition of the relationship between these two independent variables. Hurlbert (1971) gives some examples of these in his critique of the diversity concept. Nevertheless, certain properties of such a measure are clearly desirable and here much can be learned from the work of ecologists since the Second World War. Quantitative ecologists have devoted considerable effort to the development and/or application of diversity indices to the species make-up of natural communities, often with a view to relating species diversity to other community properties such as productivity and stability (Pielou 1967). Such concerns are quite analogous to the types of problem to which Fishman (1968a), Pool (1969), Lieberson (1974, 1975) and other scholars have adressed themselves. While no-one would suggest that languages obey the laws of biology, the logical problem of measuring diversity is identical in both cases. This is exemplified by the fact that the only well known measure of language diversity which incorporates both numbers of languages and corresponding numbers of users, namely, Greenberg's A-index (Greenberg, 1956), is formally almost identical to one of the more widely used ecological indices of diversity, Simpson's index (Simpson, 1949), although both appear to have been developed independently (see below, p. 7).

Pielou (1975) lists three desirable properties for a diversity index, D, which is to be a function of both the numbers of categories (languages) and the relative frequencies of items within those categories (proportions of users), D (p_1, p_2, ... p_ℓ). Weinreich (1957) has also evoked the first two of these properties while Greenberg (1956) has indicated the desirability of property (3).

Expressed in sociolinguistic terms, these may be read as :

Property 1

For any given ℓ (number of languages), D should take on its greatest value when $p_i = 1/\ell$ for all i, i.e. when users are apportioned evenly among all the languages present in the societal unit under consideration (*Note the subjectivity of the relationship between these two variables mentioned earlier; one could conceivably define diversity in exactly the opposite way*).

Property 2

Given two societal units in which users are apportioned evenly among languages, one with ℓ languages and one with $\ell + 1$ languages, then D should take on a greater value in the latter case.

Property 3

Given two societal units characterised by identical distributions of numbers of languages and users, then D should take on a greater value for a unit wherein the observed languages belong to different language groups than for a unit wherein the observed lan-

guages belong to a single language group, i.e. the diversity index should take into account the hierarchical nature of language classification and hence the concept of interlingual distance.

More formally, suppose that language users are subjected to two different classifications, namely language group classification, G, with g classes and a language classification, L, with ℓ classes. Let p_i ($i = 1, \ldots, g$,) be the proportion of speakers in the ith class of the G - classification and let p_{ij} ($i = 1, \ldots, g$; $j = 1, \ldots, \ell$) be the proportion of these speakers in the jth class of the L classification. Let $\pi_{ij} = p_i p_{ij}$ be the proportion of the whole community belonging to the ith G class and the jth L class.

Now, let D (GL) be the diversity of the doubly classified population; D (G) its diversity under the language group classification and D_i (L) the diversity under language classification of those speakers belonging to the ith G class. If, in addition, we let D_G (L) be the average of the D_i (L) over all G classes, it is then required that

$$D(GL) = D(G) + D_G(L)$$

In addition to allowing for a possible hierarchical classification of languages, property 3 would provide the possibility of measuring a population's diversity not only in terms of linguistic criteria but also in terms of kindred criteria or, indeed, totally unrelated criteria. One could conceive, for instance, of an ethnolinguistic diversity index based on a classification by ethnic affiliation and a classification by mother tongue.

Pielou (1969) has shown that the only function of the $(p_1, p_2, \ldots, p_\ell)$ proportions having these three properties is

$$(1) \qquad D(p_1, p_2, \ldots, p_\ell) = - C \sum_{i=1}^{\ell} p_i \log p_i$$

where C is a positive constant. If C is set equal to 1 we are left with the index

$$(2) \qquad D = - \sum_{i=1}^{\ell} p_i \log p_i$$

The diversity of a doubly classified population (property 3) would then be given by (Pielou, 1969)

$$(3) \qquad D_{(GL)} = - \sum_{i=1}^{g} p_i \log p_i + \sum_{i=1}^{g} p_i D_{i(L)}$$

$$\text{where } D_{i(L)} = - \sum_{j=1}^{\ell} p_{ij} \log p_{ij}$$

Diversity Measurements Using Sample Data

Equation (2) is usually referred to as the Shannon index (Shannon and Wiener, 1949) and is generally described as H', the measure of the information content of a code. In the language planning context it may be interpreted as the diversity per individual in a multilingual context. It should be noted that the Shannon index as defined in information theory is, strictly speaking, valid only for an infinite population. It measures the average information contained in a code in the long run rather that the information contained in a particular message. It should therefore be used only for societal units that are infinitely large in the sense that removing samples for them causes no perceptible change in them. [When complete census data are available diversity may be characterised quantitatively by using Brillouin's index (see below).]

The only use of this index bordering on an application to the measurement of language diversity, albeit in a non-sampling context, appears to be Sadler's (1962) little known paper. Sadler uses a different formulation of the Shannon index

$$\text{Log I} = \log N - \frac{1}{N} \sum_{i=1}^{K} n_i \log n_i \qquad (4)$$

where N is the sum of all items, (in his published examples individuals classified according to their nationality), and n_i is the number of items (individuals) in the ith category (nationality). The antilog of the resulting value, namely I, is then interpreted as a measure of the internationality of the organisations or sets of conference delegates with which he was concerned. « I tells us how many nations with equal representation would be equivalent to the observed distribution »[4]. While this interpretation of the resulting figure is a valid one in the context with which Sadler was dealing, it is perhaps unfortunate that it can result in higher measures of internationality (diversity) for organisations with narrower ranges of nationalities. This is because Sadler privileges the attainment of evenness of distribution of individuals at the expense of category diversity. This contrasts with the ecologists' approach, where a given diversity measurement is often compared with the maximum value which it could attain, given the same number of categories and a redistribution of the items involved. Although the definition of the relationship between categories and numbers of items inevitably involves a certain degree of subjectivity, as mentioned earlier, it is surely more reasonable to regard the actual number of categories as being the more important of the components, and to redistribute individuals among the categories, when evaluating diversity for distributions of maximum evenness with which to compare the diversity of observed distributions. Lieberson (1969) has stated that ratios between diversity measurements and their corresponding, maximum possible values (given the same number of categories) should not be used for comparisons between units featuring different number of categories. He suggests that such 'standardisation procedures' give misleading results in that the resulting 'standardised measures' may be strikingly different from those obtained using the basic diversity measures. It must be borne in mind, however, that evenness and diversity are different aspects of the partition of numbers of users among languages. Ratios of this type are not alternative diversity indices but rather measures of the evenness of the distribution of individuals among the various language categories. Inter-

[4] Sadler, p. 480.

unit comparisons should ideally resort to both indices, as mentioned on page (2) of the present article.

Maximum diversity for Shannon's index under conditions of complete evenness with ℓ languages is

$$(5) \qquad D_{max} = -\Sigma \frac{1}{\ell} \log \frac{1}{\ell} = \log \ell$$

The ratio of the observed diversity value to the maximum possible value (assuming the same number of individuals and languages) may then be taken as a measure of the degree of evenness of the apportionment of users to the various languages

$$(6) \qquad \text{Evenness} = \frac{D_{obs}}{\log \ell}$$

According to Poole (1974) equation (2) is a biased estimate of population diversity. Where the number of languages present in the unit under consideration is known (as it usually will be), the expected value of the observed diversity value, D_{obs}, is given by the series (Hutcheson 1970).

$$(7) \quad E\,(D_{obs}) = \left(-\sum_{i=1}^{\ell} p_i \ln p_i\right) - \left(\frac{\ell - 1}{2N}\right) + \left(\frac{1 - \Sigma p_i^{-1}}{12N^2}\right) + \left(\frac{\Sigma(p_i^{-1} - p_i^{-2})}{12N^3}\right) + \ldots$$

Natural logarithms must be used for the calculation of $E\,(D_{obs})$, the third and subsequent terms of which are usually very small. Hutcheson (1970) has also shown the variance of (D_{obs}) to be

$$(8) \qquad \text{Var}\ (D_{obs}) = \frac{-\sum_{i=1}^{\ell} p_i \ln^2 p_i - (\sum_{i=1}^{\ell} p_i \ln p_i)^2}{N} + \frac{\ell - 1}{2N^2} + \ldots$$

The $E\,(D_{obs})$ of two different samples can be compared by means of a 't' - test, to see, for example, if language diversity is changing over time. 't' would be given by (Hutcheson 1970)

$$(9) \qquad \frac{D_{obs_1} - D_{obs_2}}{|(\text{Var}\left(D_{obs_1}\right) - \text{Var}\left(D_{obs_2}\right)|^{1/2}}$$

and the degrees of freedom for the test by (Hutcheson 1970)

$$(10) \qquad \frac{[\mathrm{Var}\left(D_{obs_1}\right) - \mathrm{Var}\left(D_{obs_2}\right)]^2}{\left(\mathrm{VarD}_{obs_2}\right)^2/N_1 + \left(\mathrm{VarD}_{obs_2}\right)^2/N_2}$$

The usefulness of the preceding formulas to language planners in countries such as Canada, which are seeking to implement multicultural or multilingual policies is readily apparent. They permit regular monitoring of the national diversity situation and its evolution without resorting to cumbersome, full scale census taking. For a fuller discussion of the distributional properties of Shannon's and some other indices of diversity the reader is referred to the 1969 paper by Bowman, Hutcheson, Odum and Shenton.

In the context of the measurement of language diversity it is perhaps worthwhile mentioning that the Shannon diversity index is a special case of a more general class of functions used in the mathematical theory of information. Renyi (1961) has shown that, given a code of symbols, the function

$$(11) \qquad H_a = \frac{\log \Sigma\ p_i^{\,a}}{1 - a}$$

is the entropy of order a of the code. Setting a equal to 1 it can be shown (Pielou 1975) that

$$(12) \qquad \lim_{a \to 1} H_a = -\Sigma p_i \log p_i = D_{Shannon} = H_1$$

or the entropy of order 1 of the set of the p_i (proportions in category i). With a = 2 we obtain

$$(13) \qquad H_2 = -\log \Sigma p_i^{\,2}$$

The function Σp_i^2 is the only diversity measure which has so far received any widespread application in the field of sociolinguistics. Readers will recognize it as Greenberg's (1956) A-index which describes the probability that any two randomly picked individuals from a given societal unit will share the same mother tongue (or indeed any other linguistic or extra-linguistic feature).

It is interesting to note that Greenberg's index is almost identical to that proposed by Simpson (1949) as a measure of ecological diversity, namely

(14) $$D_{Simpson} = \frac{\Sigma n_i (n_i - 1)}{N (N - 1)}$$

where n_i = number of individuals in category i and N = total of individuals. The difference is that Simpson suggested choosing individuals without replacement. Lieberson (1969) has pointed out that essentially similar indices have in fact been developed by workers in a variety of other fields. As in the case of Greenberg's index, ecologists tend to follow Pielou's (1969) recommendation of subtracting the resulting values from unity in order to obtain an index which increases with diversity rather than uniformity. Thus

(15) $$D_{Simpson} = 1 - \Sigma \frac{n (n - 1)}{N (N - 1)}$$

and

(16) $$D_{Greenberg} = 1 - \Sigma \left(\frac{n_i}{N}\right)^2$$

This measure of diversity is widely used by ecologists and has received some application to census data on mother tongue diversity by Greenberg and later by Lieberson (1964, 1974, 1975a, 1975b).

Although it can be shown (Pielou 1969) that the Simpson index, and by extension the Greenberg index, are formally identical for both fully censused and sampled populations, it will be recalled that Shannon's formula (2) is inappropriate for fully censused populations (see page 5). When census data are available to the investigator an appropriate measure of diversity is Brillouin's index (Brillouin 1962). The measurement of the language diversity of fully censused societal units is discussed below.

It is perhaps not superfluous at this juncture to point out that Hill (1973) has demonstrated that different indices measure different aspects of the partition of items among categories. They differ in the importance which they assign to the rarer or more commonly used languages respectively. This corresponds to the inevitable subjectivity in diversity indices mentioned earlier. He suggests that, rather than taking the logarithms of entropies, which are 'harder to visualise', diversity numbers, defined as the reciprocal of the $(a-1)^{th}$ root of a weighted mean of the $(a-1)^{th}$ powers of the proportional abundances of the n categories should be used. More formally

(17) $$N_a = \left(p_1^a + p_2^a + \ldots + p_n^a\right)^{1/(1-a)}$$

where N_a is the diversity number of order a. N_0 would then measure diversity in terms simply of the number of languages present; N_1 would be $\exp(D_{Shannon})$ and N_2 would be the reciprocal of Greenberg's index, i.e. $1/(p_1^2 + p_2^2 + \ldots + p_n^2)$. As the order of the diversity number increases the importance assigned to the more widely used languages would augment.

Hill further claims that N_a is a strictly decreasing function of a and that N_1, although a transformation of Shannon's index, is in no way exceptional. However, as Pielou (1969, 1977) shows, the only function of the proportions of items, $(p_i, \ldots\ldots p_\varrho)$, having property (3) (see page 3) is Shannon's formula and it is therefore to be preferred to Greenberg's index as a more flexible tool for the measurement of the language diversity of sample data sets when this property is required.

Diversity Measurement Using Census Data

Brillouin's information-theoretic index is defined as (Brillouin 1962)

$$B = \frac{G\ !}{N_o\ !\ .\ N_1\ !\ \ldots .\ N_j\ !} \tag{18}$$

where G is the total number of symbols in a code and $N_o, \ldots, N_j$ are the numbers of symbols of each different kind. Insofar as the measurement of language diversity is concerned equation (18) may be reformulated as

$$D_B = \frac{1}{N} \log \frac{N\ !}{N_1\ !\ .\ N_2\ !\ \ldots\ N_\varrho\ !} \tag{19}$$

where N is the total number of individuals and N_ϱ is the number of speakers of the ϱth language.

D_B may be interpreted, similarly to equation (2), as the language diversity per individual. Unlike Shannon's index, D_B increases as a function of N. This should not be viewed as a drawback, however, since it is not unreasonable to expect large populations to be more diverse than small ones.

The use of logarithms ensures that D_B has the property of additivity, (3) (page 4) in addition to properties (1) and (2). In the case of very large values of N Pielou (1969) suggests the use of Stirling's approximation to the factorial

$$\ln N! \simeq N(\ln N - 1) + \tfrac{1}{2} \ln 2\pi N.$$

Thus, should it be required to take into account the hierarchical nature of language classification in a highly diverse unit such as India, for which census data were available,

one would initially define, diversity of the populations in terms of their affiliation to language groups as

$$(20) \qquad D_G = \frac{1}{N} \log \frac{N\ !}{N_1\ !\ N_2\ !\ldots N_i\ !\ldots\ N_g\ !}$$

where N_1 might be the number of individuals in the Dravidian group, N_2 those in the Indo-European group and so-on.

Language diversity *within* the ith language group would then be defined as

$$(21) \qquad D_{(L)_i} = \frac{1}{N_i} \log \frac{N_i\ !}{N_{i_1}\ !\ N_{i_2}\ !\ldots N_{i_j}\ !\ldots N_{i_{\ell i}}\ !}$$

where there are ℓi languages in the ith group, N_i is the number of individuals in language group i, and N_{i_j} is the number of users of language j. Total diversity would be given by

$$(22) \qquad D_{tot.} = \frac{1}{N} \log \frac{N\ !}{\prod_{j=1}^{\ell 1} N1j\ !\ \prod_{j=1}^{\ell 2} N2j\ !\ldots\ \prod_{j=1}^{\ell g} Ngj\ !}$$

multiplying (22) by $\dfrac{N_1\ !\ldots N_g\ !}{N_1\ !\ldots N_g\ !}$

we obtain $$D_{tot.} = \frac{1}{N} \log \left(\frac{N\ !}{N_1\ !\ldots N_g\ !} \cdot \frac{N_1\ !\ldots N_g\ !}{\prod_{j=1}^{\ell 1} N1j\ !\ldots \prod_{j=1}^{\ell g} Ngj\ !} \right)$$

$$D_{tot.} = D_G + \frac{1}{N} \sum_{i=1}^{g} \log \frac{N_i\ !}{\prod_{j=1}^{\ell i} Nij\ !}$$

multiplying by $\frac{Ni}{Ni}$ we obtain

$$D_{tot.} = D_G + \sum_{i=1}^{g} \frac{N_i}{N} D(L)_i \qquad (23)$$

Equation (23) may be extended to take in three (or more) levels of language classification such as family, group and language as follows

$$D = D_F + \sum_{i=1}^{f} \frac{N_i}{N} D_{(G)_i} + \sum_{i=1}^{f} \sum_{j=1}^{gi} \frac{N_{ij}}{N} D_{(L)_{ij}} \qquad (24)$$

In order that the non-mathematically inclined reader may find his way through this welter of subscripts, a visual example of the application of (24) to a hypothetical, threefold language classification is shown in figure 1.

While the ability to allow for the hierarchical nature of language classification would prove useful at a continental or world scale, equation (19) will probably prove adequate in most instances. The degree of evenness of the distribution of fully censused individuals among languages may be evaluated by calculating D_B / D_{max}. (Cf. equation 6). Pielou (1975, 1977) shows D_{Bmax} to be

$$D_{Bmax} = \frac{1}{N} \log \frac{N!}{(X!)^{\ell - r} (Y!)^r} \qquad (25)$$

where $X = [N/\ell]$ or the integer part of the total number of individuals divided by the number of languages, and $Y = X + 1$, so that $N = (\ell - r) X + r Y$. For the purposes of census language data analysis this expression should of course be simplified, entailing no noticeable loss of precision, to

$$D_{Bmax} = \frac{1}{N} \log \frac{N!}{(X!)^{\ell}} \qquad (26)$$

It will be recalled that the equations based on Brillouin's index are appropriate to the measurement of the diversity of fully censused populations and that there is therefore no need to calculate their standard error.

Some Other Approaches to Diversity Measurement

Pielou (1969) quotes a geometrical interpretation of the concept of diversity introduced by McIntosh (1967). McIntosh suggested that a population consisting of N individuals and ℓ discrete categories with N_i individuals in the ith category may be interpreted as a point in an ℓ-dimensional space with coordinates $(N_1, N_2, N_i, \ldots N_\ell)$. The distance

of this point from the origin, by Pythagoras' theorem, is

(27) $$H = \sqrt{\Sigma\ N_i^2}$$

The greater the number of categories (ℓ) the smaller is the distance. H may therefore be interpreted as a measure of the language homogeneity of the population. $H_{max.}$ will be attained when all individuals are assigned to a single category ($H = N$). $H_{min.}$ will be attained when every individual speakes a different language ($N = \sqrt{N}$). As with the Greenberg/Simpson index this measure would describe language homogeneity rather than language diversity. It is appropriate therefore to take

(28) $$D = N - H$$

as a measure of diversity. McIntosh further proposed

(29) $$\frac{D}{D_{max}} = \frac{N - H}{N - \sqrt{N}}$$

as a measure of diversity which is independent of the population size, N.

McIntosh also developed a measure of evenness of distribution of individuals among categories. Assuming that the number of categories (languages) may be divided into the total population exactly, resulting in $\frac{N}{\ell}$ individuals using each language then

(30) $$\text{Hmin for given } N, \ell = \left(\Sigma(\frac{N}{\ell})^2\right)^{\frac{1}{2}} = \frac{N}{\sqrt{\ell}}$$

The N - complement of Hmin for given N,ℓ is thus

(31) $$D_{max} \text{ for given } N, \ell = N - N/\sqrt{\ell}$$

The degree of evenness of a given distribution may therefore by measured by

(32) $$\frac{D}{D_{max}|N,\ell} = \frac{N - H}{N - N/\sqrt{\ell}}$$

McIntosh's index (27) is somewhat reminiscent of Weinreich's suggested D measure (1957)

(33) $$D = 1 - \sqrt{\Sigma pi^2}$$

although Weinreich advocated the use of proportions rather than of numbers of users. Weinreich's D is of course also a transformation of Greenberg's A-index; its superiority to the latter author's measure is not readily apparent, however, and it has not been employed elsewhere to the present writer's knowledge.

As a final example of the more promising methods of measuring language diversity, it is perhaps worthwhile pointing out that, in some cases, the standard deviation of the distribution of numbers of users of each language could constitute a quantitative indication of the diversity of a set of languages and their users. It would have to be interpreted with care, however, because of the weighting of extreme deviations from the mean which would be likely in this context. Furthermore, it could only be used for the comparison of societal units featuring roughly similar numbers of languages. It might nevertheless be considered for the measurement of change in diversity within a given unit over time, and has the advantage of being widely known.

Table 1 summarises the definitions and applicability of the various indices reviewed above.

The foregoing section has reviewed some of the more promising ways of measuring language diversity which are currently available to the investigator. The following pages discuss some of the pitfalls which may be encountered in seeking to apply such measures.

Problems in the Application of a Diversity Index

1. *Classification of individuals*

One difficulty in the application of a diversity index is the unambiguous assignment of individuals to a discrete language class. A prerequisite for this, as stated on page (2), is a clear statement of the subset of linguistic activities for which a diversity measurement is required, since different languages may be used for different activities. In the case of individuals using more then one language for a given activity, additional multilingual categories could be created (Greenberg, 1956). A further requirement is that languages may in fact be subjected to a discrete classification, a situation which has recently been attained, at least, on a genetic basis (C.F. and F.M. Voegelin, 1977).

2. *The modifiable unit area problem*

More intractable difficulties are raised by the definition of the areal unit for which a diversity measurement is to be made. Obviously, the measurement of the language diversity of a set of human beings requires a certain minimum level of aggregation. But, as a

TABLE 1

Index	*Definition*	*Type of data*
Shannon	$- \Sigma \frac{N_i}{N} \log \frac{N_i}{N}$	Sample data
Brillouin	$\frac{1}{N} \log \frac{N\ !}{N_1\ !\ :\ N_i\ !\ \ldots\ N_\ell\ !}$	Census data
Simpson/Greenberg	$1 - \Sigma \left(\frac{N_i}{N}\right)^2$	Sample or census data
McIntosh	$N - \sqrt{\Sigma N_i^2}$	Census data
Stand. Dev.	$\sqrt{\frac{\Sigma (N_i - N)^2}{\ell - 1}}$	Sample data (or census data with denominator = ℓ).
Weinreich	$1 \sqrt{\Sigma \left(\frac{N_i}{N}\right)^2}$	Census data

N_i = Number of users of ith language, N = total population, ℓ = number of languages.

perusal of any modern textbook in theoretical geography will reveal (e.g. Yeats, 1974, Taylor 1977, Harvey, 1969) the parameters of a spatial distribution will change according to the level of aggregation at which it is examined, often quite substantially (cf. Lieberson and O'Connor, 1975a). This, of course, is the areal aspect of the celebrated ecological fallacy (Robinson, 1950, Duncan *et al.* 1961, Scheuch, 1966). There is not space to go into the general problem in detail here, the reader will find a thorough discussion in Duncan *et al.* (1961). Scheuch sums the matter up succintly when he states :

> In the logic of inquiry it does not make any difference whether the basis for grouping individual units is a territory or some other criterion; what is essential is the effect that this criterion has on the control over the internal variability of units. Thus the general issue underlying the discussion of the ecological fallacy is really the relation of the criterion, according to which units are grouped, to the type of inference intended when using the results of aggregated units.[5]

[5] Scheuch (1966), p. 154.

Language data are usually collected on a local areal basis (census, tracts, counties, etc.) and subsequently aggregated to a greater or lesser degree prior to final presentation. The question is, at what level should the investigator work ? In the case of repeated diversity measurements within a single observational unit over time no great difficulty should be encountered, providing the unit is a meaningful one in terms of language diversity. Weinreich suggests that « ideally, boundaries should reflect actual communication patterns »[6]. Such a unit will not necessarily correspond to the administratively determined boundaries of most government data collection areas, of course. In the case of inter-unit comparisons, however, care must be exercised as such a procedure may mean that the researcher is comparing results which were obtained at radically different levels of aggregation. Greenberg (1956) pointed this out in his pioneering paper, but his advice has not always been heeded, particularly insofar as crosspolity comparisons are concerned. Is it meaningful, one may ask, to compare the language diversity of Eire (pop. < 3 mill.) with that of the U.S.S.R. (pop. > 220 mill.) ?

The modifiable unit area problem is particularly serious when one is interested in relating a measure of diversity to other variables. Lieberson and Hansen (1974), for example, examine the relationship between diversity (Greenberg's A-index) and urbanisation in the case of the U.S.S.R. at several points in time. No noticeable correlation emerges, and it is concluded that the two variables are not related. This is no doubt perfectly true, at the scale of the U.S.S.R. It must be borne in mind, however, that the linguistically diverse regions of the U.S.S.R. have not generally coincided with those characterised by high degrees of urbanisation. Percentages of city dwellers at any one time may have tended to reflect largely the situation in European Russia, while language diversity readings may have been swollen by the linguistic situation in other areas such as Soviet Central Asia. To some extent, therefore, the correlated measurements may not have referred unambiguously to the same groups of individuals, and, consequently, that which is valid at the continental scale of the U.S.S.R. may not hold at the regional scale of, say, Kazakhstan. It is interesting to note that, at the finer, regional scale, Lieberson, Dalto and Johnston (1975b) do report a noticeable, positive diversity/urbanisation correlation within the U.S.S.R.

It is even more difficult to assess the validity of cross-national (i.e. spatial) correlations where the levels of aggregation of the units of observation vary wildly among themselves (e.g. Liechtenstein and India, Luxembourg and Canada, etc.). A number of writers including the present author (Brougham, 1969) have viewed the scale phenomenon as a feature to be studied in its own right rather than as a problem to be eliminated. The concept of language diversity after all, presupposes data aggregation, and its relation to other variables implies ecological rather than individual correlations. It is therefore advisable, wherever possible, to measure diversity, and hypothesised explanatory variables, at several levels of aggregation in order to discover at which scale, if any, variation, order and relationships exist. Every effort should be made to avoid spatial correlations of language diversity measurements with other variables when units of observation are at totally incompatible levels of data aggregation.

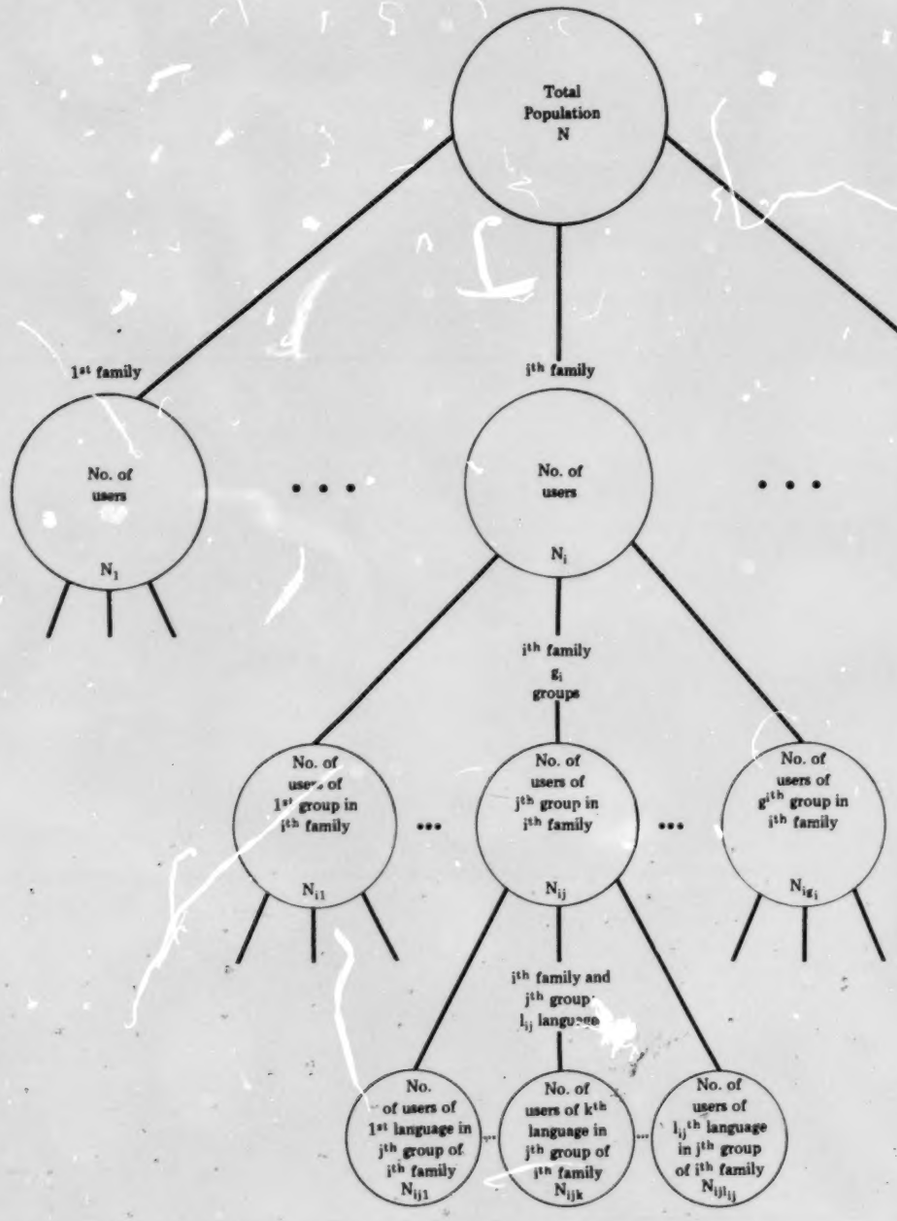
[6] Weinreich (1957), p. 227.

CONCLUSION

The preceding pages have presented the properties which one might reasonably expect a language diversity index to exhibit, and have reviewed some of the indices which are presently available for the measurement of this phenomenon, using either sample or census data. It was further suggested that one of the main problems in the measurement of diversity, and its subsequent correlation with other variables, is the definition of the observational units. Ways of attenuating this difficulty are currently being investigated at the CIRB and will be presented shortly. It is also planned to apply the more promising of the diversity indices reviewed here to the data accumulated at the Centre by Kloss & McConnell (1974, 1978, 1979) in their study of the linguistic composition of the nations of the world, thereby providing a picture of language diversity across the globe at various scales. It is also hoped that other workers will find these indices of value in terms of the evaluation and explanation of the phenomenon of language diversity.

FIGURE 1:

HYPOTHETICAL EXAMPLE OF DIVERSITY MEASUREMENT FOR A THREEFOLD LANGUAGE CLASSIFICATION USING BRILLOUIN'S INDEX



$$D_p = \frac{1}{N} \log \frac{N!}{N_1! \cdots N_i! \cdots N_f!}$$

$$D_{(G)i} = \frac{1}{N_i} \log \frac{N_i!}{N_{i1}! \cdots N_{ij}! \cdots N_{ig_i}!}$$

$$D_{(L)ij} = \frac{1}{N_{ij}} \log \frac{N_{ij}!}{N_{ij1}! \cdots N_{ijk}! \cdots N_{ijl_{ij}}!}$$

$$D_{tot.} = D_p + \sum_{i=1}^{f} \frac{N_i}{N} D_{(G)i} + \sum_{i=1}^{f} \sum_{j=1}^{g_i} \frac{N_{ij}}{N} D_{(L)ij}$$

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